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U.S. DEPARTMENT OF COMMERCE

NATIONAL BUREAU OF STANDARDS

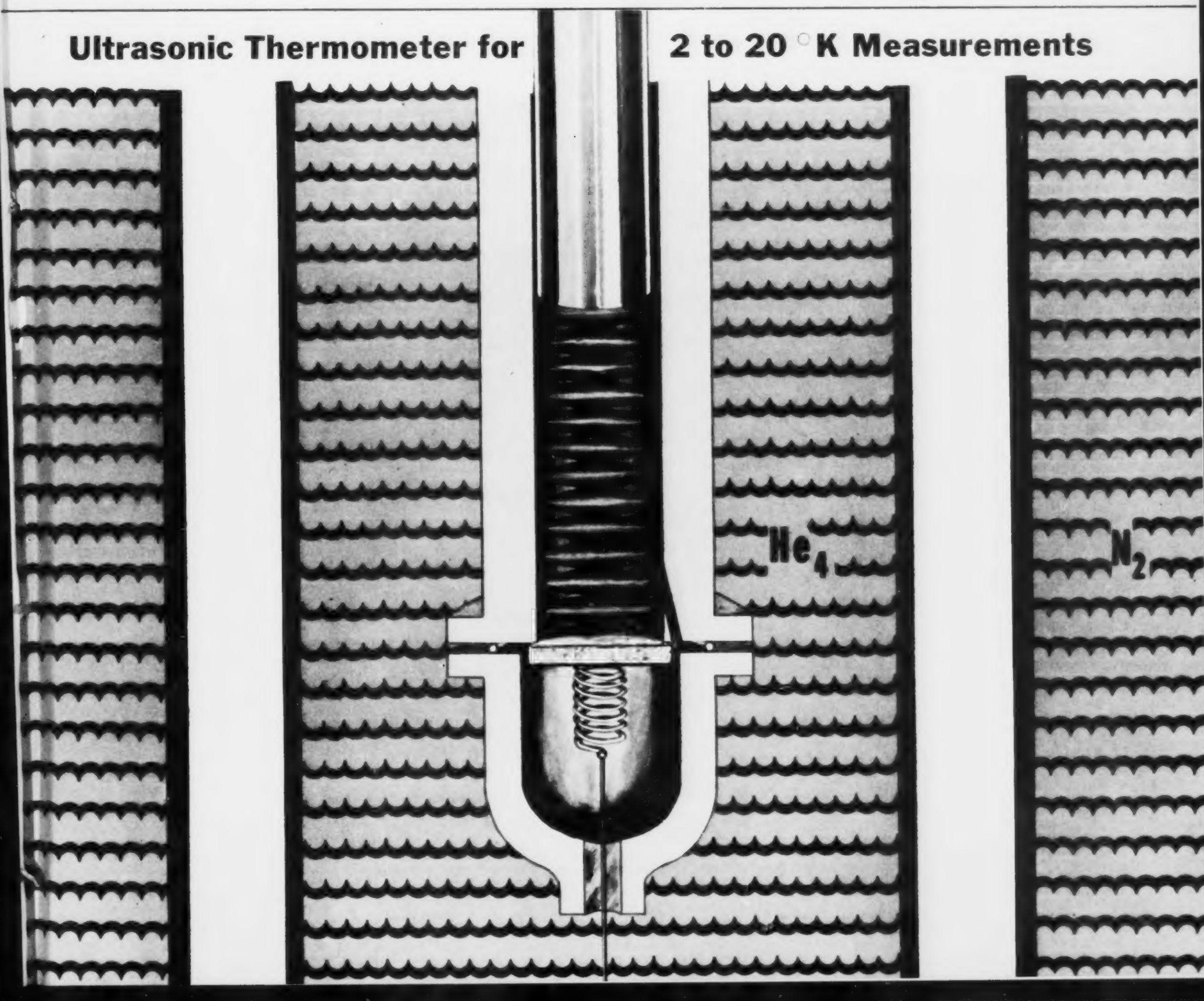
# Technical News

BULLETIN



VOLUME 47 JANUARY 1963 NUMBER 1

## Ultrasonic Thermometer for 2 to 20 °K Measurements



U.S. DEPARTMENT OF COMMERCE — LUTHER H. HODGES, *Secretary*

NATIONAL BUREAU OF STANDARDS — A. V. ASTIN, *Director*



# NATIONAL BUREAU OF STANDARDS

# Technical News

## BULLETIN

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## Contents



COVER: Schematic view of the ultrasonic thermometer developed for measuring temperature in the 2 to 20 °K range. The device is expected to establish a temperature scale between 4 and 14 °K, and to provide the basis for calibrating germanium resistance thermometers. The spring-held quartz crystal emits a precisely known ultrasonic frequency which passes through helium gas and is reflected from a piston. When the piston is an integral number of half-wavelengths from the crystal resonance occurs, and is detected by monitoring a voltage across the crystal. (See p. 4.)

# Accurate Computation of Elastic Moduli

## by improved resonance frequency technique

RECENT outstanding advances in the field of jet, rocket, and atomic-powered heat engines have strongly stimulated an accompanying development in high-temperature ceramic and cermet materials.[1] These "new ceramics" are commercially produced by methods that depart radically from orthodox procedures in the hope that they will withstand the high temperatures and corrosive atmospheres involved in such applications.

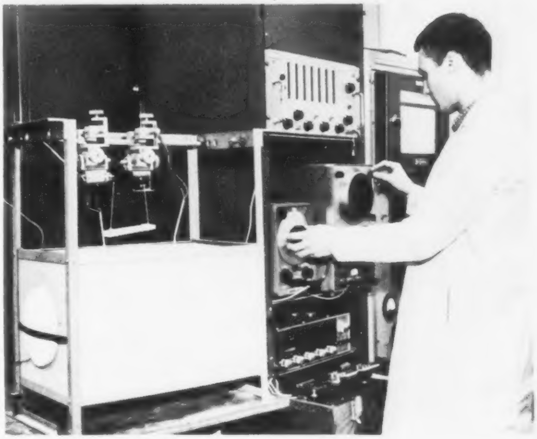
Designers have been severely handicapped, however, by insufficient data on these substances and by the fact that available data have not always been consistent. Reliable data are needed concerning mechanical strength, elastic and anelastic characteristics, temperature dependence of these properties, and thermal properties in general. Many such data can be obtained through the calculation of the elastic moduli of the new refractory materials.

More accurate relations for computing these elastic moduli have recently been developed by Sam Spinner and Wayne E. Tefft of the NBS inorganic solids laboratory. These improved relations[2] are based on results of investigations made at the Bureau using a highly refined version of the resonance frequency technique. In addition to supplying much-needed data, the studies are expected to yield a better theoretical understanding of the behavior of refractory materials.

The resonance frequency technique[3] essentially involves exciting, detecting, and measuring one of the mechanical resonance frequencies of a specimen. The equipment required for making a resonance frequency determination consists of readily available standard components—audio oscillator, audio amplifier, pickup amplifier, cathode-ray oscilloscope, frequency counter, and two transducers. The frequency response of the transducers is usually the limiting factor on the frequency response of the equipment.

The method of operation of the equipment is illustrated in the diagram on page 2. The output of the audio oscillator is amplified and fed to the driver, and also to the horizontal plates of the oscilloscope. The amplitude of vibration of the specimen is detected by the pickup, amplified, and fed to the vertical plates of the oscilloscope. When one of the mechanical resonance frequencies of the specimen is reached, the same frequency is received simultaneously by the horizontal and vertical plates of the oscilloscope, and a Lissajous pattern is presented on the screen. The oscillator frequency setting at which this pattern has its maximum vertical amplitude is one of the resonance frequencies of the specimen.

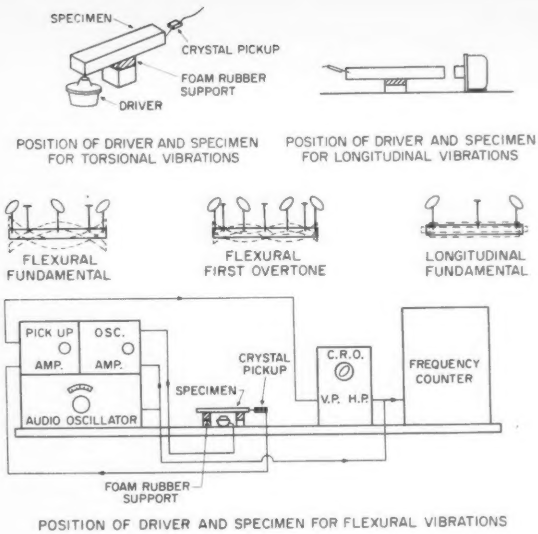
One of the advantages of the resonance frequency technique is the relative ease with which it can be adapted to both high- and low-temperature measurements. At the Bureau,[4,5] measurements have been made over a range from about −80 to +1400 °C. Extreme care has been taken to keep the specimen free of any load imposed by the driver and pickup mechanisms, and to eliminate any environmental effects.



**In making dynamic resonance frequency measurements, the specimen is suspended** *(at left)* **in the position required during room-temperature studies. For measurements at higher temperatures, the specimen is suspended within the furnace** *(below the specimen)* **in much the same manner. Larry Stone varies the frequency of the oscillator, which feeds the driver that excites the specimen, while adjusting the gain of the oscilloscope, which presents a Lissajous pattern on the screen. The oscillator frequency setting at which this pattern has its maximum vertical amplitude is one of the resonance frequencies of the specimen.**

The technique has been refined to such an extent that with reasonable care it is now possible to determine room-temperature resonance frequencies to an accuracy of about 1 part in 5,000, which is a considerable improvement over previous results. If extra care is taken—mainly to allow the specimen to come to equilibrium with a controlled ambient temperature—resonance frequencies can be measured to better than 1 part in 10,000.

The equations for relating the resonance frequencies, dimensions, and densities of specimens are based on the classical theory of elasticity. It would seem, then, that when the density and dimensions of the specimen are known to an accuracy comparable with that of the resonance frequency, the appropriate elastic moduli




**Apparatus used for dynamic resonance frequency measurements. The output of the audio oscillator is amplified and fed to the driver, and is also transmitted to the horizontal plates of the oscilloscope. The driver causes the specimen to vibrate as the frequency of the oscillator approaches a resonance frequency of the specimen. These vibrations are detected by the pickup and sent to the vertical plates of the oscilloscope. When the oscillator reaches a resonance frequency of the specimen, the oscilloscope receives the same signal on both sets of plates and displays a Lissajous pattern of maximum vertical amplitude.**

could be computed to the same order of accuracy. This has not been the case, however, because even for the simpler shapes (such as cylindrical rods and square and rectangular bars) the equations themselves were not known with sufficient accuracy. Approximations that were adequate as long as the resonance frequencies were known to only about 1 percent or less became unsatisfactory.

Efforts to improve this situation resulted in an important new utilization of the Bureau's resonance frequency determinations. Data obtained in these studies served as the basis on which Spinner and Tefft empirically established relations for determining elastic moduli from resonance frequencies, densities, and dimensions of cylindrical rods and square and rectangular bars. These relations usually are in the form of corrections to be applied to the best available appropriate theoretical equations, or, in certain cases, to the development of new relations.

The general approach to this work has been to select a group of specimens in such a manner that uniformity of intrinsic moduli and density is insured, and variations in dimensions are known to be consistent. The resonance frequencies of these specimens are then determined and the desired modulus-resonance frequency relation is established.

Steel specimens generally have been chosen because steel can be machined fairly easily to high dimensional accuracy, and it is inexpensive and dimensionally stable. Also, if reasonable care is exercised, a steel can be selected that maintains uniform elastic moduli and density among various specimens, is homogeneous and isotropic, and responds very well elastically under the experimental conditions imposed. The results are not peculiar to steel, however, but should apply to any elastic, homogeneous, isotropic material, with the qualification that Poisson's ratio must also be considered for Young's modulus and its related modes of flexural and longitudinal vibration.

Similar empirical relations have been developed for various modes of vibration. For example, Young's modulus can be computed from the flexural (transverse) vibrations of cylindrical rods and rectangular bars, and shear modulus can be accurately determined from the torsional vibrations of square bars. The most recent work [5] of this kind to be completed is the development of equations for computing Young's modulus from the longitudinal vibrations of square bars and cylindrical rods.

## Application of Experimental Method

The term "nondestructive" is usually interpreted as meaning that the specimen is not destroyed or obviously damaged during the measurement process. Although such an interpretation is certainly correct when applied to resonance frequency measurements, a more subtle meaning may be inferred. Since the resonance frequencies are determined on the basis of minute stresses and strains (near the zero stress level), the possibility of minor—perhaps unsuspected—changes occurring in the specimen during the process of measurement is reduced to a minimum. Consequently, the experimenter can be fairly certain that any changes detected in the material under study are the result of changes in relevant experimental parameters rather than of effects introduced in the measuring process itself.

When making measurements as a function of temperature, one can distinguish between reversible temperature-dependent effects and nonreversible ones introduced during heat treatment by noting whether or not the specimen has the same value of resonance frequency after being heated as it had before heating. Through these changes in resonance frequency, changes in the various elastic moduli with temperature can be determined. Generally, flexural (transverse) vibrations, associated with Young's modulus, and torsional vibrations, associated with shear modulus, are tracked as functions of temperature. Knowledge of these two moduli permits complete specification, elastically, of isotropic materials. The different moduli do not necessarily vary with temperature in the same manner, as was shown in a recent study [6] of the elastic moduli of vitreous silica.

When successive room-temperature measurements of elastic moduli are made on a group of specimens to study some particular effect, changes in the values of elastic moduli are usually found to be associated with changes in other properties of the specimens. Correlation of these changes serves as a basis for analysis of structural changes that take place within the material. In glasses, for example, refractive index and density are known to change in a definite manner with heat treatment. A recent study[7] has shown that the elastic moduli of glasses also change with heat treatment, and that these changes in moduli can be uniquely related to the associated changes in refractive index and density. This discovery has helped to extend the "fictive temperature" concept[8] related to annealing (viz, that the condition of a glass as a function of heat treatment can be characterized not only by its refractive index or density, but also by its elastic moduli).

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[1] Properties of high-temperature ceramics and cermets—elasticity and density at room temperature, *by S. M. Lang, NBS Mono. 6 (1960). For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C. Price 20 cents.*

[2] Comparison of theoretical and empirical relations between the shear modulus and torsional resonance frequencies for bars of rectangular cross sections, *by Sam Spinner and Rudolph C. Valore, Jr., J. Research NBS* **60,** *No. 5, 459 (1958)*; A comparison of experimental and theoretical relations between Young's modulus and the flexural and longitudinal resonance frequencies of uniform bars, *by S. Spinner, T. W. Reichard, and W. E. Tefft, J. Research NBS* **64A** *(Phys. & Chem.), No. 2, 147 (1960)*; Cross-sectional correction for computing Young's modulus from longitudinal resonance vibrations of square and cylindrical rods, *by Wayne E. Tefft and Sam Spinner, J. Research NBS* **66A** *(Phys. & Chem.), No. 2, 193 (1962)*: Torsional resonance vibrations of uniform bars of square cross section, *by Wayne E. Tefft and Sam Spinner, J. Research NBS* **65A** *(Phys. & Chem.), No. 3, 167 (1961).*

[3] A method for determining mechanical resonance frequencies and for calculating elastic moduli from these frequencies, *by S. Spinner and W. E. Tefft, Proc. ASTM* **61,** *1221–1238 (1961).*

[4] Temperature dependence of elastic constants of some cermet specimens, *by Sam Spinner, J. Research NBS* **65C** *(Eng. & Instr.), No. 2, 89 (1961).*

[5] Temperature dependence of Young's modulus of vitreous germania and silica, *by S. Spinner and G. W. Cleek, J. Appl. Phys.* **31,** *No. 8, 1407–1410 (1960).*

[6] Temperature dependence of the elastic constants of vitreous silica, *by Sam Spinner, J. Am. Ceram. Soc.* **45,** *No. 8, 394–397 (1962).*

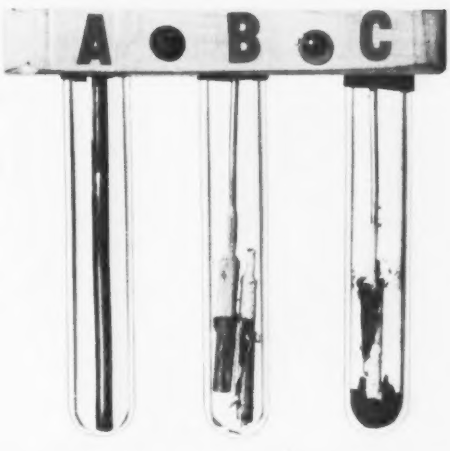
[7] Relation between refractive index and elastic moduli of a borosilicate glass after heat-treatment, *by Sam Spinner and Albert Napolitano, J. Am. Ceram. Soc.* **39,** *No. 11, 390–394 (1956).*

[8] *The word "fictive" continues to be used because of its wide acceptance in the literature: "fixative" would be a more appropriate term to express the concept of a temperature corresponding to a frozen-in condition. See* Viscosity and the extraordinary heat effects in glass, *by A. Q. Tool, J. Research NBS* **37,** *No. 2, 73 (1946) RP1730: Ceram. Abstr., Jan., p. 7 (1947)*: *Changes* caused in refractivity and density of glass by annealing, *by A. Q. Tool, J. Research NBS* **38,** *No. 5, 519 (1947) RP1793; Ceram. Abstr., Sept., p. 153i (1951).*

# METAL DEPOSITION INVESTIGATED FOR URANIUM

## as a means of inhibiting corrosion

URANIUM, used as a fuel element in atomic reactors, is subject to corrosion when its surface is exposed to air or moisture. In efforts to inhibit this corrosive process, the Bureau, in cooperation with the Atomic Energy Commission, has been evaluating the effectiveness of metallic coatings deposited on the surface of uranium. Recent experiments indicate that coatings electrodeposited from nonaqueous media lend better protection to uranium than do coatings electrodeposited from water solutions, but that only moderate adherence between the basis metal and metallic coatings can be achieved. During the course of the work, a useful method was found for determining the porosity of electrodeposited coatings.[1]




**Specimens showing results of electroplating metals on uranium. (*A*) Uncoated uranium rod sealed in an evacuated tube turned dark, indicating the presence of corrosion products; (*B*) Copper-plated specimen (*left*) and aluminum-plated specimen (*right*) in which poor adhesion was found; (*C*) Aluminum-plated specimen, heated in a hydrogen atmosphere, produced black uranium hydride blisters which later ruptured.**

Uranium is difficult to protect from corrosion because it is chemically active. In dilute acids or alkalies, uranium is attacked with the evolution of hydrogen; in the atmosphere it soon becomes covered with a black oxide film. Unlike the highly protective oxide films that form on other active metals such as aluminum or magnesium, this uranium oxide film gives little protection. Uranium surfaces have been found to absorb materials during the electroplating process, resulting in a slow deterioration of the uranium-to-coating bond. The present investigation was therefore undertaken to study reactions as well as coating adhesion problems under varied electroplating conditions.

### Experimental Procedure

Preliminary experiments showed that metals such as copper, nickel, and chromium electrodeposited on uranium specimens from aqueous plating baths were not very adherent and could be removed quite easily. Specimen surfaces were found to be metallic if their coatings were detached immediately after plating; when an interval of a month or more elapsed before removal of the coatings, the uranium surface was blackened, indicating the presence of corrosion products.

Since previous work [2] had shown that aluminum could be electrodeposited from a hydride-aluminum chloride-ether bath, this anhydrous process was used in further experiments. When the aluminum coating was later removed, no black film had formed. Some specimens coated in this manner and stored for periods up to six months retained a clean metallic surface between the base and plating metal. However, in these experiments only moderate adhesion was found.

A method for depositing zinc on uranium was then employed; zinc acetate-formamide was used as the plating solution. This bath yielded zinc coatings with considerable adhesion; but when the specimens were sectioned, an undesirable tan oxide film was found between the uranium and the coating. Other zinc plating formulas produced no tan oxide formation but exhibited poor zinc adhesion.

In a few experiments, zinc coatings deposited on uranium from the vapor phase were investigated. The uranium was heated in a rotating evacuated tube together with zinc and powdered silicon carbide. The abrasive silicon carbide particles served to keep the uranium surface clean and free from any oxides that might form during plating operations. Zinc, having an appreciable vapor pressure, was deposited directly upon the uranium surface, forming a zinc-uranium alloy which exhibited fairly good adherence. This method shows some promise as a means of protecting uranium surfaces but additional experiments are necessary to fully evaluate its effectiveness.

### Porosity of Uranium Coatings

A simple method for determining the porosity of electroplated coatings on uranium was developed as a byproduct of these experiments. In this method, the plated specimen is stored for 24 hr in an evacuated vessel, which has partially been refilled with hydrogen and heated to approximately 200 °C. At this temperature, any uranium exposed through a pore in the plating is attacked by hydrogen and converted into uranium hydride, a bulky black powder. The formation of the hydride at the site of the pit causes a visible blister; in extreme cases, the coating actually ruptures. This test is easy to conduct, and the presence of small amounts of oxygen, nitrogen, or moisture do not affect the results.

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[1] *For further technical details see* Preparation of and electroplating on uranium, *by D. E. Couch, Plating Magazine, American Electroplater's Society, April 1962. Present address of Mr. Couch: U.S. Bureau of Mines, 500 State Street, Boulder City, Nevada.*

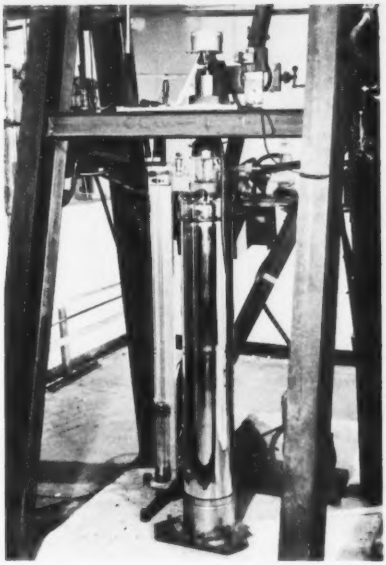
[2] A hydride bath for the electrodeposition of aluminum, *by D. E. Couch and A. Brenner, J. Electrochem. Soc.* **99**, *234 (1952).*

# Ultrasonic Thermometer for Low-Temperature Determinations

THE ULTRASONIC thermometer [1] has been refined at the Bureau to the point where temperature measurements in the range 2 to 20 °K can be made with great accuracy and precision. Based on the determination of the speed of sound in helium gas, the ultrasonic thermometer is expected to establish an absolute temperature scale in the region 4 to 14 °K, and to provide the basis for the calibration of germanium resistance thermometers. This thermometer eliminates the troublesome corrections required with gas thermometry, and the need for precise volume and pressure determinations. The program is under the direction of H. H. Plumb of the cryogenic physics laboratory.

Accurate measurement of the speed of sound provides a means of determining absolute temperatures, as the speed in an ideal gas is proportional to the square root of the temperature. In practice, of course, a real gas is used and consideration must be made of the effects of pressure. With the ultrasonic thermometer, the speed is determined at several pressures sufficiently low that a plot of speed versus pressure is linear and can be extrapolated to zero pressure. This procedure eliminates the need for pressure corrections and gives the speed in an ideal gas.

In essence, the ultrasonic thermometer is a resonance tube (fixed frequency, variable path length) used to



*Left:* **Ultrasonic thermometer used to make accurate temperature determinations in the 2 to 20 °K range. The thermometer, contained within the tall Dewar flask** (*center*), **contains a quartz crystal to provide sound of known frequency, and a movable piston that permits the establishment of successive states of gas resonance within the tubular cavity. By measuring the displacement of the piston, and the number of resonance states occurring during this movement, the wavelength of the sound can be determined. From the wavelength, the speed, and then the temperature, can be calculated.**

*Below:* **As the calculation of temperature from the speed of sound in gas is based on the speed in an ideal gas, measurements of the speed are made in the ultrasonic thermometer at several different pressures. This plot of speed versus pressure is then extrapolated to zero pressure, giving the speed under ideal-gas conditions. The procedure eliminates the need for accurate knowledge of the virial coefficients of the gas.**

determine the wavelength of sound. At the lower end of the tube an oscillator-driven quartz crystal supplies sound of a known frequency (near 1 Mc/s); a movable piston forms the upper reflecting surface. Helium gas at low pressure (runs have been made at from 0.01 to above 2 atm) fills the cavity. The helium gas is set into resonance whenever the reflecting surface of the piston is an integral number of half wavelengths away from the crystal. This resonant condition is detected by strip-chart monitoring of a small voltage applied across the crystal, peaks appearing on the chart whenever resonance occurs. Measurements are made by moving the piston toward or away from the crystal through a large number of half wavelengths and, from a measure of the displacement of the piston and the number of peaks on the chart, the wavelength of the sound is determined. From the wavelength, since the frequency is known, the speed can be computed from the relation: *speed = frequency × wavelength.*

Once the speed at zero pressure has been determined, the absolute temperature $T$ is calculated from the equation

$$W_0^2 = \left(\frac{C_p}{C_v}\right)_{p=0} \frac{R_M}{M_{\mathrm{He}}} T$$

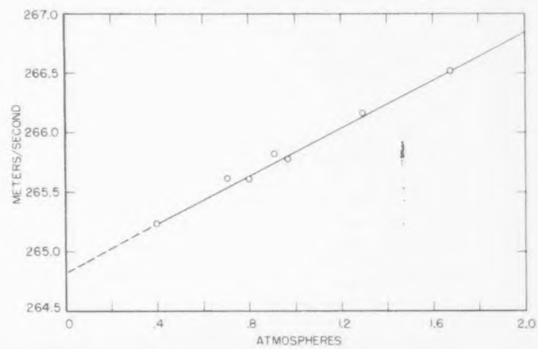
where $W_0$ is the speed at zero pressure,

$$(C_p/C_v)_{p=0} = 5/3, \quad R_M = 8.314 \text{ erg/°C Mol}, \text{ and } M_{He} = 4.0026.$$

Measurements to date with the ultrasonic thermometer indicate a reproducibility of $\pm 0.002$ deg at 2 °K and $\pm 0.007$ deg at 20 °K, and close agreement at these temperatures with determinations made by other techniques.

In what additional temperature regions the ultrasonic thermometer will be competitive with other techniques is not presently known, as the initial emphasis of the program is on filling the gap in the 4 to 14 °K range. Later studies will seek to extend the range of usefulness. As the ultrasonic thermometer in itself is not conveniently useful for routine temperature measurements, a parallel program in low-temperature measurements with germanium resistors is also under way at the Bureau. It is through these secondary devices that the scale established with the ultrasonic thermometer will be used in general applications.

[1] *For further details, see* The detemination of absolute temperatures from sound velocity measurements, *G. Cataland, M. Edlow, and H. H. Plumb, in* Temperature, its measurement and control in science and industry, pt. 1, vol. 3, *Reinhold Publ. Corp. (New York) 1962. See also* Absolute temperatures determined from measurements of the speed of sound in helium gas, *by G. Cataland and H. H. Plumb, presented at the 8th International Congress on Low Temperature Physics, London, Sept. 1962, and* The acoustical interferometer employed as an instrument for measuring low absolute temperatures, *by G. Cataland and H. H. Plumb, J. Acoust. Soc. Am.* **34,** *1145 (Aug. 1962).*



# NBS Studies Radiation Pattern of Monopole Array

RADIO propagation scientists at the NBS Boulder (Colo.) Laboratories have verified theoretically obtained radiation patterns for an antenna array composed of 31 monopoles arranged in two concentric circles, using an actual model of the array. The investigation was sponsored by the U.S. Air Force (Ground Electronics Engineering Installation Agency and the Electronic Systems Division) to determine the suitability of such antenna arrays as medium-beamwidth, steerable communications antennas.

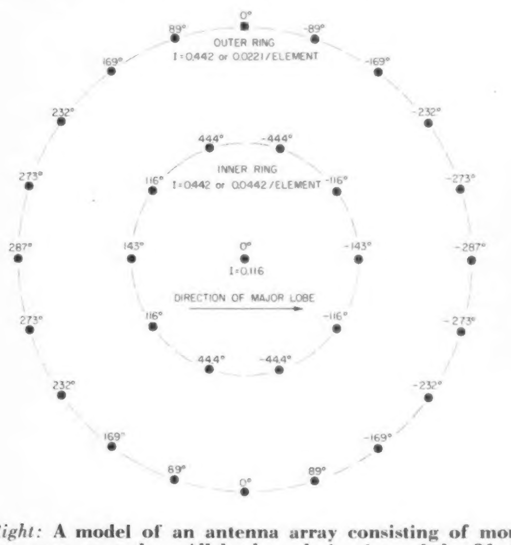
The array model was mounted on a turntable in a radiofrequency field and its directionality determined for various turntable positions. The radiation pattern obtained was similar to that expected from theoretical considerations, except for previously unevaluated "shading effects" caused in each element by its proximity to others.

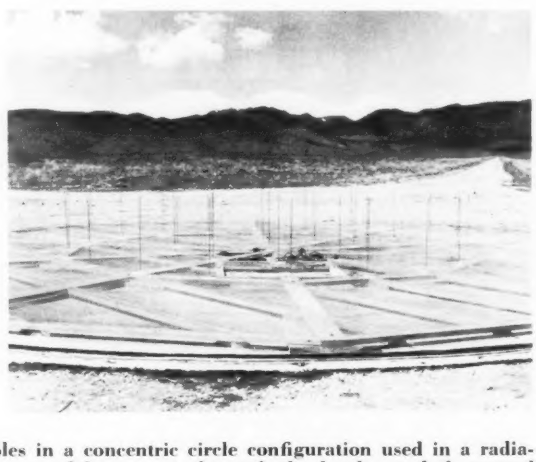
A transmitting or receiving array consists of many similar antenna elements, physically spaced or connected by phase-shifting circuitry in a manner designed to produce phase reinforcement and directional characteristics. A single vertical monopole just above the ground plane will radiate most strongly horizontally, but equally well in all horizontal directions; several such monopoles can be positioned in an array on a ground plane to obtain directional characteristics. The investigation conducted at the Bureau's Boulder Laboratories was intended to verify the mathematically predicted radiation pattern and the steerability of an array of monopoles having the configuration of two concentric circles around a center monopole.

The antenna array used in this investigation consisted originally of a single quarter-wavelength monopole surrounded by two concentric circles of identical monopoles placed at quarter-wavelength intervals around the circumference, one having a radius of 0.4 wavelength and the other, 0.8 wavelength. All of the monopoles were mounted on a ground plane formed of hardware cloth; the whole assembly could be rotated with the large turntable on which it was constructed at the Boulder Laboratories' Table Mesa antenna test site. A frequency converter was used at each monopole, with the circuitry mounted in a shielded enclosure directly below the ground plane. The signal received at each monopole (90 Mc/s) was shifted in phase by being heterodyned with a locally generated 60-Mc/s signal of proper phase, resulting in a converter output containing a 30-Mc/s component having the desired phase relationship to the other heterodyned signals.

The radiation pattern of the array was determined experimentally by testing it as a receiving array; that is, by measuring its cumulative output for varied turntable positions in the field of a remote target transmitter. Both the radiation pattern and the optimum phase relationships for greatest array directionality had been computed previously. The relative phases of individual elements were first set to the optimum values; the radiation pattern was then recorded as total array output as the turntable was slowly rotated.

The experimental results demonstrated close agreement between the theoretical and recorded radiation pattern of the phased circular array. The main lobe was found to be nearly identical in both, while the measured sidelobes were within $\pm 1$ db of the predicted



*Right:* **A model of an antenna array consisting of monopoles in a concentric circle configuration used in a radiation pattern study. All leads and circuitry of the 31-element model array are beneath the hardware-cloth ground plane. Recordings of reception by the array as the turntable is rotated showed the actual radiation pattern to be almost identical with the theoretically derived one.** *Left:* **Plan view of circular antenna showing element phasings.**

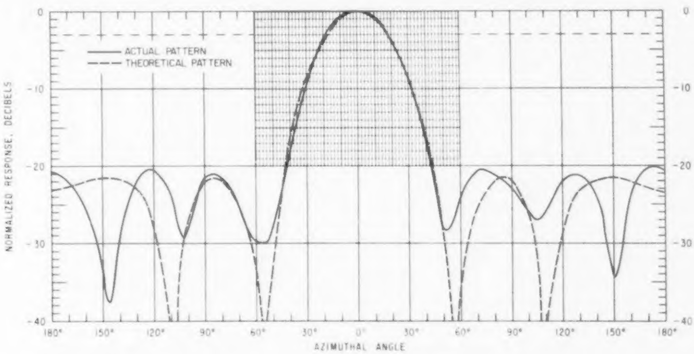
sidelobes and slightly displaced from them. The main lobe had a half-power beamwidth of 35°, while the sidelobes peaked at 20 db below the main lobe.

The beam from such an array used in communications systems would be steered through 360° by control of the relative phasing of the elements, but steerability of the beam was not included in this study. Changes in the radiation pattern with changes in steering were, however, of great interest. The array is identical physically every 36°, hence the pattern will be identical at these points during steering. The pattern was checked at 9° and 18° from these points of symmetry and was found to remain constant except for slight increases in sidelobe levels. This finding verified that the directional characteristics of the array would not be greatly changed with steering.

In early work with the circular array it was found that the quarter-wavelength monopoles originally used exhibited marked directionality due to shading by adjacent elements. The elements were shortened experimentally to diminish this effect until, at 0.21 wavelength, satisfactory operation was obtained.

The contributions to total array current were determined by making measurements on the array during reception testing. It was found that each of the two rings contributed 0.442 of the total current and the center element the balance of 0.116 of the total current.

The ideal communications antenna should be useful over a wide range in frequencies, but the model array radiation pattern was found to be quite sensitive to changes in frequency. This was determined by recording the radiation pattern for a complete revolution of the turntable for frequencies varied in 1-percent steps from the 90–Mc/s design frequency. With the resulting change in electrical length of all components, the pattern developed additional lobes and altered impedances. Shading effects increased as the frequency was increased toward resonant proportions. When frequency was decreased, shading diminished but element mutual impedances increased. The growth of sidelobes with change in frequency and particularly the appearance of a backlobe at increased frequencies indicate that antennas of this design are inherently limited in bandwidth.




**Directional radiation pattern obtained from an array of monopoles in a concentric circle configuration by correctly phasing each of the 31 elements. Recording of the actual radiation pattern (*solid line*) obtained is almost identical to the theoretically obtained pattern (*dashed line*) in the vicinity of the major lobe.**

# TEMPERATURE AND HUMIDITY EFFECTS ON THIN FILM ASPHALTS

A RAPID spectroscopic technique has been used at the Bureau to measure the combined effects of temperature and humidity on air-blown asphalts. Experimental data showed that both factors contribute to asphalt oxidation, with temperature having the more pronounced effect. The study was made by P. G. Campbell, J. R. Wright, and P. B. Bowman of the organic building materials laboratory as part of a continuing program for investigating the constitution and degradation of asphalt.[1]

Chemical and physical reactions contributing to the degradation of asphalts include polymerization, dehydrogenation, oxidation, and migration of the oil phase to the surface. Of these factors, oxidation has the most detrimental effect. Asphalts oxidize steadily with time, and the rate of such oxidation is influenced by environmental factors.

Previous experiments at the Bureau[2] showed that asphalt degradation could be greatly accelerated when specimens only 25 microns thick were used. The method employed in these experiments involves measuring the infrared spectrum of the film, exposing the film to a source of radiant energy, and then remeasuring its infrared spectrum. Oxidation of the film



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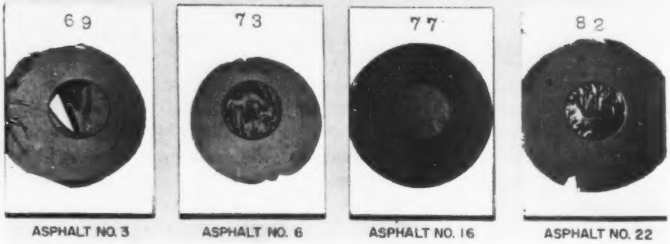


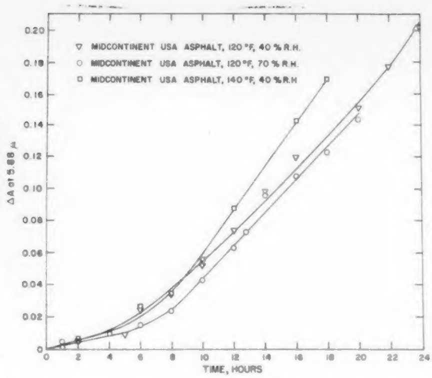


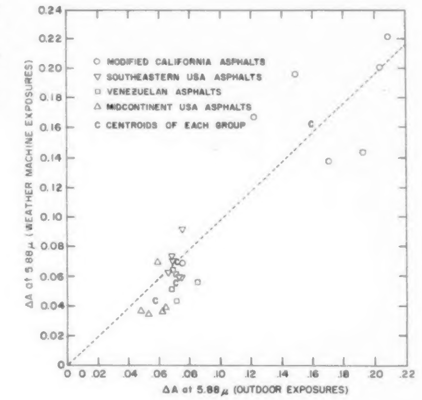


***Above:* Thin film asphalt specimens of different durabilities show the effects of being exposed for 8 hr in an apparatus held at 130 °F and 70 percent relative humidity.** *Right, top:* **Typical curves of 3 samples of the same asphalt during oxidation. The increase in infrared absorption ($\Delta A$) increases with time, and changes with temperature and humidity. The initial portion of the curves shows an induction period followed by a steady oxidation rate.** *Right, bottom:* **Close infrared absorption correlation obtained between thin film asphalt species exposed to natural weathering conditions and to accelerated weathering conditions. Centroids of each group fall close to the broken line which represents an ideal curve when all factors affecting oxidation both indoors and outdoors are exactly the same.**

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is determined from the resulting change in absorbance in the carbonyl band (5.88 μ). In the present study, the same method was applied to determine the effect of atmospheric conditions on asphalt oxidation.

Specimens for the experiments were obtained from commercial manufacturers of asphalt roofing materials, and included materials from many geographic locations. Thin film specimens made from these materials were exposed to temperature-humidity conditions in an accelerated weathering machine and in actual outdoor tests.

In the weathering machine, temperature and humidity were controlled for specific time periods. A carbon arc was used as a source of radiation in the apparatus. Tests were run at steps ranging from 110 to 150 °F, and relative humidity was maintained at 17, 40, and 70 percent levels for each temperature step determination. Exposure times varied from a half-hour to twenty-four hours.

In the outdoor tests, specimens placed on a rack at an angle of 45° facing south were exposed for 96 hr. A sheet of window glass was placed over the specimens to protect the thin films from physical damage. Temperatures during these exposures ranged from 26 to 68 °F, and humidity varied from 28 to 89 percent.

Data obtained from both the weathering machine tests and the outdoor tests were in good agreement. Results of this study show that asphalt oxidation varies directly with temperature and humidity, as indicated by the carbonyl absorption spectra.

Although infrared spectral data are valuable for determining oxidation rates in thin film specimens, additional information is required for theoretically interpreting the observed effects of temperature and humidity on asphalt oxidation. Such information would include data on the amount of oxygen absorbed in the reactions, identification of gaseous decomposition products, and the influence of ozone or other atmospheric oxidants. However, the application of a theory developed for temperature and humidity effects on coal oxidation[3] to asphalt oxidation suggests that the latter may be caused by the formation and subsequent decomposition of an asphalt-oxygen-water complex.

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[1] *For further technical information see* The effect of temperature and humidity on the oxidation of air-blown asphalts, *by P. G. Campbell, J. R. Wright, and P. B. Bowman, Div. Petroleum Chem. (ACS) preprint, Sept. 1962; also Materials Research and Standards (in press).*

[2] Determination of oxidation rates of air-blown asphalts by infrared spectroscopy, *by James R. Wright and Paul G. Campbell, Div. Petroleum Chem. (ACS) preprint, March 1962; also, J. Appl. Chem. (London)* **12,** *256 (1962).*

[3] The mechanism of the oxidation of coal (II), *by R. E. Jones and D. T. A. Townsend, Inst. of Gas Eng. Res. Fellowship Rpt., 132–158 (1944–45); and* Some aspects of the kinetics of oxidation of coal (I); The correlation of coal oxidation kinetics, *by T. Wood, J. Appl. Chem. (London)* **8,** *565 (1958).*

# Photoelectronic Measurement of Vibratory Displacements

A HIGHLY precise technique for measuring small vibration displacement amplitudes, developed at the Bureau for the Special Projects Office of the U.S. Navy, is now being used in calibrating vibration pickups. The technique resulted from the work of V. A. Schmidt, S. Edelman, E. R. Smith, and E. T. Pierce of the acoustics laboratory; [1] it uses photoelectronic measurement, in place of visual inspection, of an interferometer fringe pattern to identify vibration amplitudes, even in the presence of considerable "jitter." The increased precision with which vibration amplitudes are determined by this technique has proved to be of considerable value in calibrating the vibration instrumentation required by today's advancing technology.

Measurements of vibration are becoming increasingly important and must be made with greater accuracy to keep pace with the increasing precision and speed of modern mechanical systems. The needs of space technology, in particular, have extended the range over which the response to vibration of both materials and men must be known. Vibration pickups for making these measurements are calibrated by being secured to the table of a "shaker," or vibrating machine, and their electrical output measured for known vibration frequency and amplitude.

In calibrations the vibration frequency and the voltage generated by the transducer are easily measured by conventional laboratory instruments, but precise measurement of vibration amplitude has always been a problem. In earlier work it was found that interferometers, which are well suited to the measurement of small static displacements, can identify vibratory displacements also. One method of using an interferometer depends on an unusual visual effect. The bands in a fringe pattern fade to a uniform field at specific axial vibration displacement amplitudes of one interferometer plate because of the integrating action of the eye.[2] The vibration amplitudes at which this occurs can be computed and used as calibration points. In this way amplitudes as small as 1045 A (approximately $10^{-7}$m) have been detected with mercury-green light.

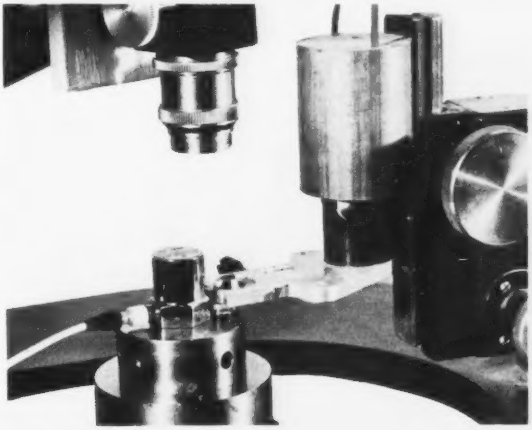
In practice the fringe disappearance technique has not proved entirely satisfactory for calibration work. Not only does each fringe disappearance mark a finite range of visually indistinguishable amplitudes (where increased precision could be obtained only by reducing the range of undiscriminable measurements), but this range is widened in the presence of "jitter," which can be due to extraneous vibration or too compliant a support.

The present investigations have shown how a valuable increase in precision can be obtained by a method using an electronic null indication rather than the observer's eye to detect the same vibration amplitudes. This photoelectronic method also greatly reduces the effects of jitter, permitting measurements to be made even when jitter is present.

In this new method an additional controlled relative vibration is given to the interferometer plates by driving the upper plate with a small piezoelectric driver operating at a frequency different from the shaker frequency. A photomultiplier tube (photoelectric cell with built-in amplifiers) is used to sense changes in interference pattern and an oscilloscope and meter to indicate them. A high-$Q$ bandpass filter, set to the frequency of this new driver, is inserted between the photomultiplier and the indicator.

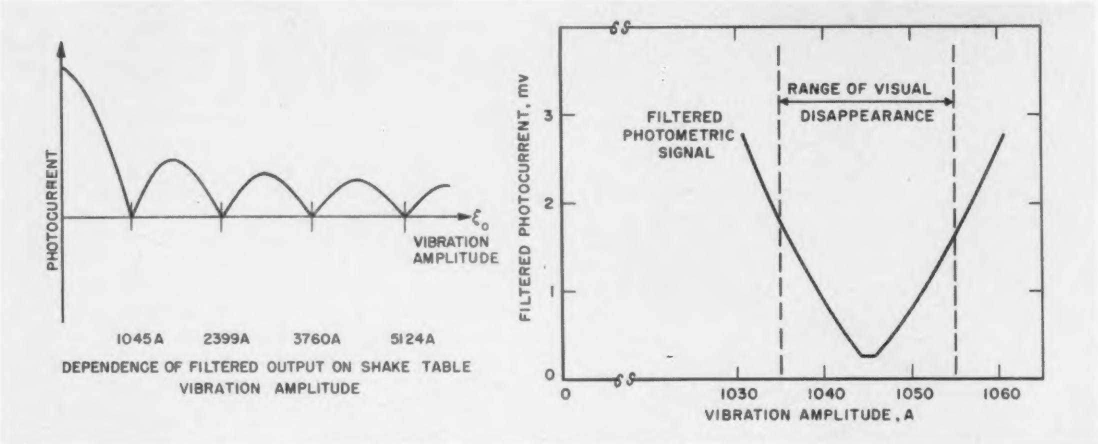
Mathematical study shows the indicator null to be determined by a Bessel function, in the Fourier expansion of an expression for the photomultiplier tube current, containing terms depending on the vibration amplitude and the wavelength of light used in the interferometer. Nulls in the filtered photomultiplier signal identify the calculated series of vibration amplitudes. These amplitudes are the same as those found by visual fringe disappearance.

The improved fringe inspection is performed using an equipment setup that is optically the same as for visual fringe disappearance, with the addition of the photomultiplier tube. A ceramic piezoelectric driver vibrates the support for the upper interferometer plate (a 0.875-diopter plano-convex lens) to modulate the



**Vibration pickup secured to the table of a shaker in preparation for calibration of its response to known vibration amplitudes. The lower interferometer reflecting surface is a glass plate secured to the shaker table beside the pickup being tested. The upper reflecting surface is a lens supported by an arm extending from a small piezoelectric driver (*right*). Electrical oscillations applied to the driver are transferred to the upper reflecting surface as vibration modulating the interference fringe pattern.**

*Left:* **Graph of photomultiplier current versus vibration amplitude sensed by an interferometer using 5461-A light shows characteristic nulls which permit identification of known calibration amplitudes.** *Right:* **Enlarged portion of plot including a null shows** *(within dotted lines)* **range within which the human eye cannot detect change in vibration amplitude, extending nearly 1 percent on each side of the true value. New photoelectronic null detection technique developed at NBS improves precision in setting amplitude to better than 0.5 percent.**




fringe pattern at an audio rate. The audio source and the bandpass filter are set to the same frequency, typically between 30 and 3000 c/s. The photocurrent nulls obtained at the calibration amplitudes are identified, with the equipment used at the Bureau, by the disappearance of the a-c component at the upper plate frequency from the amplified and filtered photomultiplier signal. Good results were obtained when the shaker and upper plate frequencies differed by at least a factor of five. The high-$Q$ bandpass filter, together with the water-cooled mercury vapor lamp used as a source of 5461-A mercury-green light for the Fizeau-type interferometer, make possible a 50-db signal-to-noise ratio in observing the nulls.

The photoelectronic method can be used to identify amplitudes as small as 1045 A, the first null found with the use of 5461-A mercury-green light. Other amplitudes can be identified for higher-order nulls and for different light wavelengths. Smaller displacement amplitudes can be identified by means of an interpolation technique developed at NBS.[3]

The technique described may be used at any frequency where good shaker motion is available. Uniaxial sinusoidal motion of low distortion and sufficient amplitude is required for precise calibration. Thus far, calibrations have been made at selected shaker frequencies covering the range from 50 c/s to 30 kc/s. At frequencies up to 10 kc/s it is estimated that the overall errors of the calibration do not exceed ±2 percent.

[1] Modulated photoelectric measurement of vibration, *by V. A. Schmidt, S. Edelman, E. R. Smith, and E. T. Pierce, J. Acoust. Soc. Am.* **34,** *455 (Apr. 1962).*

[2] Electromechanical pick-up calibration by the interferometer method, *by G. A. Ziegler, J. Acoust. Soc. Am.* **25,** *135 (Jan. 1953).*

[3] Optical calibration of vibration pickups at small amplitudes, *by V. A. Schmidt, S. Edelman, E. R. Smith, and E. Jones, J. Acoust. Soc. Am.* **33,** *748 (June 1961).*

*Left:* **E. T. Pierce makes precalibration adjustment of equipment used to identify vibration amplitudes in calibrating vibration pickups. The upper oscilloscope trace represents the amplified and filtered photomultiplier signal and the lower trace the unfiltered signal. The upper trace flattens out at certain amplitudes to indicate nulls identifying displacement amplitudes in a calculated series.** *Right:* **Pierce visually inspects interference pattern in preoperational adjustment. The equipment includes a Fizeau-type interferometer with a monochromatic light source (connected to the coolant tubing,** *left***) and a shaker (***bottom***) for vibrating items secured to its table. Components added to improve calibration accuracy are a small piezoelectric driver and a photomultiplier (***top,*** served by two cables).**

# Cooling of Liquid Hydrogen by Injection of Helium Gas

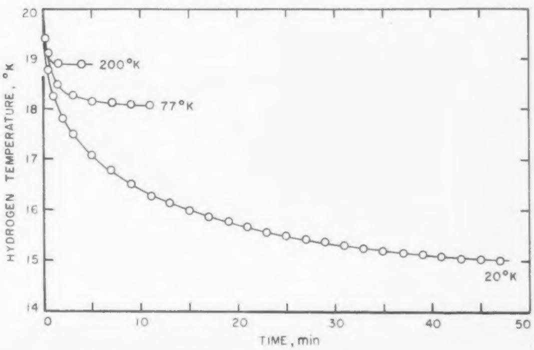
A RECENT study by the Bureau should make liquid hydrogen more readily adaptable for use as a rocket fuel. A pre-launch problem with vehicles using hydrogen or other cryogenic propellants is that environmental heating in the tube leading from storage tank to delivery pump may cause pump cavitation and faulty combustion. To overcome this situation, Alan Schmidt,[1] of the Cryogenic Engineering Laboratory at Boulder, Colo., has investigated, under National Aeronautics and Space Administration sponsorship, the cooling of liquid hydrogen by the bubble-through of helium gas. This technique was found to subcool the hydrogen enough—through evaporative cooling—to provide the pump with properly conditioned fluid immediately prior to rocket engine firing. Previous studies[2] at NASA's George C. Marshall Space Flight Center had shown this technique to be effective with liquid oxygen, whose boiling point is some 70 deg Kelvin above that of hydrogen.

## Experimental Apparatus

The test facility includes a cryostat containing a stainless steel pipe with a working height of 3.5 m and a capacity of 72 l (about 19 gal) of liquid hydrogen. A thin tube within the hydrogen pipe supports a series of eleven gold-cobalt versus copper thermocouples, referenced to a parahydrogen vapor pressure bulb at the bottom of the tube.

Gaseous helium is piped down through a heat exchanging unit and enters the bottom of the liquid hydrogen pipe. The heat exchanger can be left at ambient temperature or filled with cryogenic liquids. The helium temperature at the injection orifice is measured by a thermocouple. The entire assembly—liquid hydrogen pipe and helium entry apparatus—is enclosed within an outer cryostat shell. Evacuated powder is used as the insulating medium within the system, and variable heat input to the column can be achieved through partial destruction of the vacuum.

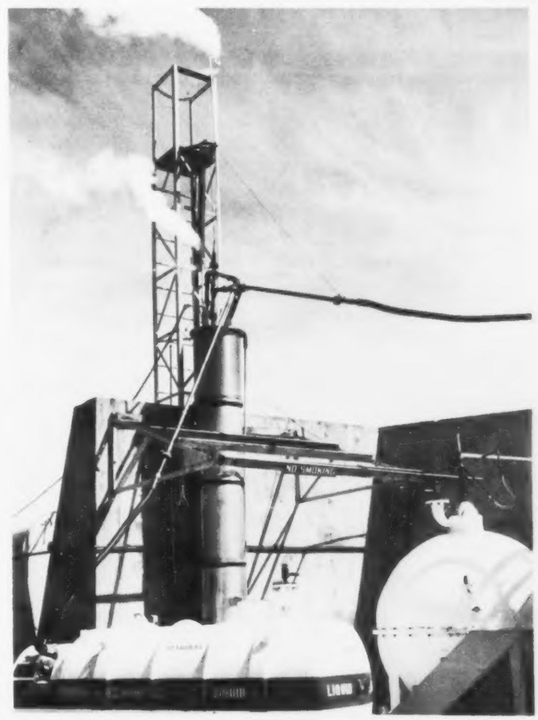
**_Below:_ The temperature history of the liquid hydrogen column as a function of the temperature of the helium gas. Flow rate was 283 slm, and heat flux about ¼ millijoule/sec/cm² of column wall. _Right:_ Most of the test equipment used to prove the helium "bubble through" method for cooling liquid hydogen is contained within the cylindical cryostat shown in the center of the photo.**




## Procedure

Before a run is made, the hydrogen pipe is filled to overflowing, and, if cryogenic cooling of the helium is to be used, the heat exchanger is filled with an appropriate cryogen. No provision is made for topping off the central hydrogen column, but fluid is added to the heat exchanger to keep it near capacity.

A timer is started when helium flow is initiated, and selective thermocouple readings, vapor pressure bulb readings, and helium injection cylinder pressure drop readings are made at predetermined intervals. The run is terminated when no temperature change, as determined by the vapor pressure reading, can be detected over a 5-min interval. Such parameters as gas flow rate, gas temperature, and heat influx are varied over different runs.



## Results

As might be expected, the temperature to which the hydrogen can be cooled and the time required for the column to reach thermal stability are dependent on the heat influx, the gas flow rate, and the temperature of the helium. For example, flow rates in excess of 283 standard liters per minute (slm), when the heat load was $\frac{1}{4}$ millijoule/sec/cm$^2$ of column wall area, resulted in steady-state temperatures of 15 °K when the helium was cooled with liquid hydrogen and 18.1 °K when cooled with liquid nitrogen. When the helium gas was injected at liquid hydrogen temperature and the heat input was increased to 20 millijoules/sec/cm$^2$ of wall area, equilibrium temperatures of 18.2, 17.7, and 17.0 °K resulted at the corresponding flow rates of 311, 509, and 877 slm. These results are in close agreement with the analytical treatment of the earlier NASA–MSFC study on liquid oxygen.

[1] Experimental investigation of liquid hydrogen cooling by helium gas injection, *by Alan F. Schmidt, presented at the 1962 Cryogenic Engineering Conference, Los Angeles, Calif., and to be published in the* Proceedings.

[2] Subcooling of cryogenic liquids by injection of noncondensing gas, *by W. O. Randolph and J. L. Vaniman, George C. Marshall Space Flight Center, MTP–S & M–P–61–19.*

# NBS Boulder Laboratories Aids World Data Center Operation

SINCE 1957 the NBS Boulder Laboratories has been serving as a subcenter for collecting International Geophysical Year (IGY) airglow and ionospheric research data. To date, this subcenter has accumulated nearly 15 million feet of 35-mm film containing such data. Copies of these records are being sent to other World Data Centers in the coordinated IGY program and are made available to scientists needing data in the fields covered. Valuable assistance is thus given to studies of physical processes taking place in the ionosphere and other regions of the earth's outer shell.

The International Geophysical Year program was organized and is directed by the Comite Special de l'Annee Geophysique Internationale, to make available to scientists all over the world data on physical processes taking place on, in, and around the earth. Virtually all countries possessing scientific staffs and facilities have participated in gathering these data, which are now available to all scientists.

The IGY program was supported in the United States by the National Science Foundation. Although most of the IGY data have already been collected and sent to the World Data Centers by the collecting stations, the data centers throughout the world will continue to copy and catalog data, making them available to interested scientists.

The IGY program includes activities in the areas of 14 disciplines, each a branch of physical sciences related to the earth and its physical environment. These fields are meteorology, geomagnetism, aurora, airglow, ionosphere physics, solar activity, cosmic rays, longitude and latitude, glaciology, oceanography, rockets and satellites, seismology, gravity, and nuclear radiation.

Data in each discipline are sent from each of the scattered observation stations to one of the three World Data Centers (WDC) established under this program: WDC–A is located in the United States, WDC–B in the U.S.S.R., and the 14 single-discipline subcenters of

*Left:* **Reels of 35-mm film, kept in a humidified storage vault at NBS Boulder Laboratories, form a large part of the data cataloged and stored as the IGY World Data Center–A for Airglow and Ionosphere. The reel being returned to the rack by Frances Stryker had been lent to a scientist for study. Tags hanging from racks identify reels borrowed for study or research.** *Right:* **A visiting scientist from Japan and a guest worker examine a reel of ionograms on 35-mm film, as Sidney Ostrow (left), describes the data available to the scientific community at the IGY World Data Center–A.**

WDC–C in various places in Western Europe and the Western Pacific. WDC–A is divided into 11 data subcenters, each assigned to an institution having a background of lively interest and scientific competence in that discipline. The Airglow and Ionosphere subcenter is at the Boulder Laboratories of the Bureau; Instrumental Aurora at College, Alaska; Visual Aurora at Ithaca, N.Y.; Cosmic Rays at Minneapolis, Minn.; Geomagnetism, Gravity, and Seismology at Washington, D.C.; Glaciology at New York, N.Y.; Longitude and Latitude at Washington, D.C.; Meteorology and Nuclear Radiation at Asheville, N.C.; Oceanography at Washington, D.C.; Rockets and Satellites at Washington, D.C.; and Solar Activity at Boulder, Colo.

Each WDC is assigned the tasks of making a complete collection of information (raw data in some cases, reports in others) for the discipline it is responsible for, cataloging it, copying it, supplying copies to other data centers for the same discipline, and suppling copies to any scientific body or investigator in any country on request, at cost. Duplication of information in three data centers is intended to make it more readily accessible to scientists, regardless of nationality, and to be a safeguard against the possibility of catastrophic loss of the results of so much scientific effort.

The NBS Boulder Laboratories was selected to serve as the WDC–A subcenter for Airglow and Ionosphere Studies because of the long record of the NBS Central Radio Propagation Laboratory in research on radio propagation, airglow, and ionosphere physics. The National Science Foundation allotted IGY funds to support this work at CRPL beginning in September 1957. Operation of the Airglow and Ionosphere WDC–A at the Boulder Laboratories is now directed by A. H. Shapley and supervised by G. A. Lira of NBS.

Facilities provided at the Boulder Laboratories for operation of this WDC–A subcenter include microfilm readers and copiers; scaling tables for ionograms; a humidified vault for storage of ionograms, microfilm records, and other filmed records; and offices for visiting scientists using the data center archives.

During the International Geophysical Year the Boulder data subcenter received records consisting, for the most part, of ionograms from 167 vertical incidence sounding stations, 73 of which were nominally assigned to WDC–A. Not all the vertical incidence sounding stations remained active beyond the end of the IGY, but about 50 percent more than the pre-IGY number are still in operation.

The ionospheric data collected have been of several categories: (1) hourly values of ionospheric characteristics, (2) median height and diurnal plots for several layers of ionization, (3) plots of critical frequencies versus time, and (4) ionograms of frequency versus reflection time on 35-mm film (in addition to catalogs of data, some pre-IGY data, and correction factors for known errors). Airglow data, of smaller volume but equal importance in research, consist of observations of emissions at 5577, 5893, and 6300 A and of the OH bands. The data are received in a variety of forms, the 35-mm ionogram film being most common. Data in this form and on microfilm are stored in the humidified film-storage vault; conventional filing cabinets are used for data sheets, data books, and published reports; and many data are filed encoded on punched cards.

Film footage on hand has grown from 400,000 ft in 1958 to 12,000,000 ft by May 1962. The high level of ionogram recording activity since the IGY has maintained the rate of data received at about the same level as in 1959. During the first six months of operation, beginning in November 1957, 24 orders for data and records were filled. The volume of orders filled tripled by 1959, and in 1960 more than 100 orders were handled. Orders for copies of data are received from both the United States and other countries.

The services offered by world data subcenters are contributing to worldwide and regional geophysical research programs by cataloging and supplying data which would have far less value if used only in station-by-station studies. The IGY program will encourage joint research in related scientific disciplines and, most important, encourage the growth of a worldwide scientific community.

# SYMPOSIUM ON PHOTOGRAPHY OF ELECTRONIC DISPLAY

NEARLY 300 scientists and engineers using photographic methods to observe or record phenomena attended a Symposium on Photography of Electronic Display at Washington, D.C., Oct. 12 and 13, 1962. The Symposium, sponsored jointly by the Bureau and the Society of Photographic Scientists and Engineers (SPSE), featured a welcoming address by Dr. Allen V. Astin, NBS Director, a talk, "The Photogenic Electron," by Dr. Allen B. DuMont of the Allen B. DuMont Laboratories, and an invited paper, "The Recording of Light Images and Electron Beams," by Dr. Heinz Nitka of Ansco. The program included technical papers on newly developed techniques and details for photographing electronic displays in scientific investigations and military applications.[1]

The refractometry and photographic research laboratories of the Bureau are engaged chiefly in improving measurement techniques and the precision obtained with these techniques in photographic applications. Other NBS laboratories use photographic techniques as tools in scientific work—for example, to capture short-lived phenomena, to study the microstructure of materials, and to observe turbulent flow, shock waves, or similar density variations obtained with schlieren optical systems. The Bureau joined SPSE in sponsoring the present meeting to facilitate the dissemination of new photographic techniques used in the sciences, industry, and education.

The Symposium was opened by Chairman Dwin Craig, of LogEtronics. He presented Dr. Astin, who in welcoming the conferees noted the appropriateness of NBS cosponsorship of the Symposium, inasmuch as NBS staff members were among the scientists founding SPSE in 1947. He stressed the Bureau's concern with physical measurements and the instruments and techniques for making them, as well as the usefulness of such symposia in advancing measurement techniques.

C. S. McCamy, Chief of the NBS photographic research laboratories and Chairman of the Papers Committee for the Symposium, introduced Dr. DuMont, who is well known as a pioneer in the development of the cathode ray tube (CRT) and

its applications. In his keynote talk Dr. DuMont first noted that the CRT is superior for electronic indications because its display, obtained from an electron beam, is inertia free and inherently suited for responding to high-frequency voltage changes. Dr. DuMont then described stages in the development of the CRT, from the first cold-cathode, magnetically deflected one in 1897, to the present large, bright, sensitive, and long-lived CRT's. He concluded with descriptions of modern devices for still and motion picture oscillography.

The first technical session of the Symposium, moderated by Hutson Howell of Itek Laboratories, was devoted to the practical considerations of matching the recording device to the photographic medium and of determining optimum exposure. Specific attention was given to several CRT phosphors and variables affecting exposure.

The second session, moderated by Dr. Francis J. Heyden, S. J., of Georgetown University, gave additional consideration to exposures required for various CRT phosphors. The techniques needed to record on-board radar presentations and the development of a radar display recorder were described. Characteristics of a recently developed two-color (cyan and red) photographic paper and details of its rapid processing were given. A method of processing conventional silver halide reversal film at temperatures elevated to between 120 and 140 °F was reported to permit processing times of as little as 10 sec, including bleach and redevelopment steps, plus washing and drying times.

The third session opened with the invited paper of Dr. Heinz Nitka. In this paper Dr. Nitka described the relationship between light sensitivity and image resolution for image-recording systems using photographic films or photoelectronic devices. He emphasized that the resolution and sensitivity are restricted by the fundamental limits of the sensor's quantum efficiency.

This session, moderated by Dr. Francis E. Washer of the NBS refractometry laboratories, continued with a discussion of factors—such as light transmission and resolution characteristics—that affect the use of fiber optic CRT faceplates. The variables considered in production, including crosstalk and stray light absorption, were enumerated and the application of phosphor to the plates described. Another paper dealt with the necessity of matching the resolution capabilities of the photographic and electronic components of a mixed system. The session was concluded with a report on the use of sine-wave response (modulation transfer) methods and an analog computer to determine compensation for the nonlinear density-versus-exposure characteristics of an electro-optical system.

In the final session, moderated by Dr. Lyman Chalkley, President of SPSE's Washington chapter, the photographic aspects of the TIROS weather-photographing satellite were discussed. The satellite-borne portion of the system consists of two television-type cameras. The ground equipment of the TIROS system permits photographs to be made of the CRT presentation, obtained from the satellite signal. In other papers, methods of determining CRT beam current as a function of deflection plate current and the use of a selenium plate in making ultraviolet recordings of CRT presentations were described. A new medium, an electron-sensitive film on which black areas corresponding to electron beam position appear with thermal development, was introduced. The film requires no lens, no phosphor, and no silver compounds, thus permitting simple and quick use.

The session was concluded with a description of two methods for visual identification of portions of magnetic tape on which information is recorded. These methods were developed to permit visual monitoring of tape-recorded information obtained during missile firings. In one method, a coating of minute transparent capsules containing mobile magnetizable particles is used; particle alinement in a magnetic field produces visible changes. This material can be erased and re-used. In the other method, the coating contains compounds which undergo chemical reactions in the presence of a magnetic field to produce easily identified color changes. Copies of the color pattern can be made by contact with a similar unchanged tape.

[1] Various papers presented at the Symposium will appear in *Photographic Science and Engineering*, the bimonthly journal of the Society of Photographic Scientists and Engineers.

# OMNITAB:

# A Second-Generation General Purpose Computer Program

OMNITAB, a computer program that permits scientists and others unfamiliar with programming to communicate with a 7090 computer using simply written sentence commands, has been developed by Joseph Hilsenrath, Guy G. Ziegler, and Philip J. Walsh of the Bureau staff. OMNITAB is used for the calculation of tables of functions, for solutions of nonlinear equations, for curve fitting, and for statistical and numerical analysis of tabular data. The ease with which OMNITAB provides access to the computer makes it a tool that will pave the way to more rapid computation of routine laboratory problems.

Most computers require that a program (or code) be prepared before even a relatively simple problem can be run. These are usually formulated by a specialist. The necessity to learn a programming language forms a bottleneck in the man-machine system. This is especially true for university students and for the average experimental or theoretical scientist or engineer. OMNITAB removes this bottleneck by allowing the user to communicate with the machine directly through *simple sentences* made up of numbers and familiar English words.

OMNITAB was designed and written primarily for those persons whose problems are normally performed on desk calculators. An underlying motive for its creation was to relieve these people from routine day-to-day hand computing. OMNITAB gives them a means of direct man-to-computer communication in a language they best understand. However, OMNITAB is by no means restricted to this special group of personnel—it can also be a valuable aid to professional programmers. With OMNITAB, various sections of problem analysis can be checked independently in order to determine proper programming procedures, data can be checked for validity, and one-shot jobs can be done with a working program.

OMNITAB, by allowing the user to prepare his own data for processing, has accomplished several useful ends: (1) The computer is now as readily available as a desk calculator because of the ease with which problems can be formulated for solution. (2) Problems

that may have, in the past, been withheld from the computer because of the need for programming, can now be solved in greater detail and in less time than formerly. (3) The responsibility for the data, both its accuracy before going into the computer and the types of operations to be performed on it, now rests solely with the person who is most familiar with the problem—the scientist. (4) Programmers who formerly spent considerable time devising routines for relatively straightforward problems will now be free to handle more important tasks.

A wide variety of mathematical and manipulative procedures are available in the OMNITAB routine. In addition to the basic arithmetical operations, there are provisions for raising to powers, use of logarithms to base 10 and base *e*, elementary and special functions, curve fitting, integration, differentiation, interpolation and many others. The program has a capacity of 7,200 results, arranged in 36 columns of 200 rows each.

A "statistical analysis" package, which computes the average of a set of numbers (200 maximum) and 30 statistical measures related to the average, dispersion, randomness, and other properties of the distributions, has been incorporated in the program. This analysis, which takes only a fraction of a minute on the machine, should have a beneficial standardizing influence on the statistical analysis of laboratory data.

The instructions to the computer, as well as the data to be manipulated, are prepared for entry to the machine on punched cards. Simple sentences are used to indicate the allowed operations. For example, one instruction in a series might read

MULTIPLY COLUMN 3 BY COLUMN 4, STORE IN COLUMN 5

or, in abbreviated form,

MULTIPLY 3 BY 4, STORE IN 5

or even shorter still as

MULTIPLY 3, 4, 5.

The figures in a column can be operated on by those in another column or by constants. The presence of a period after a number indicates that the number is to be read as itself, whereas the absence of a period indicates a column of numbers. Thus the two sentences

ADD 2. TO 3, STORE IN 4; and, ADD 2 TO 3, STORE IN 4

have different meanings. In each instruction, the last figure indicates a column in which the results are stored. Each sentence gives a unique command for a specific type of operation, a series of commands being necessary for the computation of a problem (see example).

The result of an operation can be stored in a column or added to the data already in a column. Differentiation of these two procedures is accomplished by the inclusion of an extra "MULTIPLY" term to provide cumulative multiplication. For example,

MULTIPLY COL 2 BY COL 3, STORE IN COL 4

will result in the product of this operation being put in column 4 by clearing that location prior to storage.

MULTIPLY COL 2 BY COL 3, MULTIPLY BY 1., ADD TO COL 4

instructs the computer to add the product to data already in column 4.

Function generation is achieved by such sentences as:

LOGE OF COL 4, MULT COL 2, ADD TO COL 7

ERROR FUNCTION OF COL 1, MULT BY 1.8735, STORE IN COL 5

TAN OF 1.8 RADIANS, MULT BY COL 3, ADD TO COL 7

Other mathematical operations are obtained by such sentences as:

STATISTICAL ANALYSIS OF COL 3, WEIGHTS IN COL 2

DERIVATIVES OF COL 2, USE 5 POINTS, H=1., STORE IN COLS 3, 4, 5

FIT COL 2, WEIGHTS IN COL 3, VECTORS IN COLS 1, 4, 5, 6

POLYFIT COL 2 WEIGHTS IN COL 3, USE 5TH DEGREE POLYNOMIAL

PLOT COLS 2, 3, 4, 5, 6, AGAINST COL 1

DIFFERENCE COL 3

Additional features of the program include a variety of manipulative operations, flexible input and output formats, and options to punch cards, plot graphs, abridge tables, etc. Finally, a built-in dictionary permits OMNITAB to accept instructions not only in English but in French, German, and Japanese as well.

A typical problem and the OMNITAB instructions for its solution is presented below.

### *Typical Problem and Omnitab Instructions*

Compute the Einstein functions:

$$-G=-\ln(1-e^{-x})$$
$$H=xe^{-x}(1-e^{-x})^{-1}$$
$$C=x^2 e^{-x}(1-e^{-x})^{-2}$$
$$S=-G+H$$

for $X=.01(.01)2.$

```
            LIST OF OMNITAB COMMANDS
                   LIB 7,10000
IDENTIFICATION HILSENRATH 4-19-62
TITLE1 EINSTEIN FUNCTIONS
GENERATE .01(.01)2.00 IN COL 1
NEGEXP OF COL 1, STORE IN COL 2
MULTIPLY COL 2 BY -1. STORE IN 3
ADD 1. TO COL 3 STORE IN 3
LOGE OF COL 3, MULT BY -1., ADD INTO 4
RAISE COL 3 TO -1., MULT BY COL 2, ADD 5
MULTIPLY COL 5 BY COL 1, STORE IN 5
ADD COL 4 TO COL 5 STORE IN COL 6
DIVIDE COL 5 BY COL 2, MULT BY 5, ADD 7
HEAD COL 1/     X
HEAD COL 4/     G
HEAD COL 5/     H
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# New Appointments at NBS Boulder

Russell B. Scott has been named Acting Director of the Bureau's Boulder, Colo., Laboratories. The former Director, Dr. F. W. Brown, is taking a leave of absence to serve as scientific attaché at the American Embassy in Buenos Aires, Argentina. Bascom W. Birmingham has been designated Acting Chief of the Cryogenic Engineering Laboratory, replacing Mr. Scott.

In another appointment, C. Gordon Little was named Chief of the Central Radio Propagation Laboratory. Dr. Little also succeeds Dr. Brown who had been acting in this position in addition to serving as Director of the Laboratories. Jack W. Herbstreit was appointed Assistant Chief of CRPL.

The Central Radio Propagation Laboratory has primary responsibility within the U.S. Government for collecting, analyzing, and disseminating information on the propagation of radio waves at all frequencies along the surface of the earth, through the atmosphere, and in outer space. The work of the laboratory is divided into four areas: ionosphere research and propagation, radio propagation engineering, radio communications and systems, and upper atmosphere and space physics.

Other changes in CRPL include the appointment of Ernest K. Smith as Chief of the Upper Atmosphere and Space Physics Division, and Robert W. Knecht as Chief of the Ionosphere Research and Propagation Division.

### Russell B. Scott

Mr. Scott has been Chief of the NBS Cryogenic Engineering Laboratory at Boulder since it was established in 1954. A veteran of more than 34 years' service with NBS, he started with the low-temperature section of the Bureau in 1928. In September of 1948 he was appointed Chief of the Cryogenic Physics Section in Washington.

Mr. Scott was born in Ludlow, Ky., in 1902. He attended the University of Cincinnati, Ohio, for two years, later transferring to the University of Kentucky, where he was graduated cum laude with a B.S. in physics in 1926. He earned his M.S. in the same field at the University of Kentucky in 1928.

During World War II, while working for the Bureau, he was involved in the determination of properties of uranium compounds in support of the Manhattan Project.

### C. Gordon Little

Dr. Little has been Chief of the Upper Atmosphere and Space Physics Division of CRPL since May 1960. He joined the staff of NBS in 1958 as a consultant in radio astronomy, ionospheric physics, and radio wave propagation. He is the author of twenty papers on satellite and ground-based observations of the upper atmsophere. He recently received wide acclaim for his authorship of a special report by the National Academy of Sciences-National Research Council to the Federal Council for Science and Technology on aeronomy, the branch of science that deals with the earth's upper atmosphere to its outer boundary with interplanetary plasma. With Robert S. Lawrence, he shared the 1961 Boulder Scientist Award of the Scientific Research Society of America (RESA).

### Jack W. Herbstreit

Mr. Herbstreit, who has been Assistant Chief of the Radio Propagation Engineering Division since 1957, has served with NBS since 1946. He received the Harry Diamond Award for "original research and leadership in radio propagation" from the Institute of Radio Engineers in 1959, and was elected a Fellow of IRE in 1958. He is currently the chairman of a group revising the Joint Technical Advisory Committee book, "Radio Spectrum Conservation."

### Bascom W. Birmingham

Mr. Birmingham, who joined NBS in 1951, is a graduate of MIT, where he received a B.S. (1948) and an M.S. (1951), both in mechanical engineering. He was a design engineer with the consulting engineering firm of W. R. Holway and Associates, Tulsa, Okla., from 1948 to 1950, where he worked in the steam power field. As a part of his early work at NBS, Mr. Birmingham assisted with the installation of the large-capacity hydrogen liquefying equipment at Boulder. He later served as chief of the Cryogenic Equipment Section

Scott

Little

Herbstreit

Birmingham

Smith

Knecht

and in this capacity was responsible for the design of experimental vessels for the storage and transportation of liquefied gasses, including suitable refrigeration equipment. He represented NBS as consultant and advisor to the University of California Radiation Laboratory at Berkeley, on the design of a large liquid-hydrogen bubble chamber to be used in conjunction with the bevatron high-energy particle accelerator.

### Ernest K. Smith

Dr. Smith succeeds C. Gordon Little, who was recently appointed Chief of the Central Radio Propagation Laboratory. Since joining the Bureau's staff in 1951, Dr. Smith has investigated such ionospheric phenomena as sporadic-*E*, *F*-region anomalies and studies of the atmospheric refractive index for non-ionized gases.

Born in Peking, China, on May 31, 1922, Dr. Smith attended the Yenching University Faculty Children's School and the Peking American School. He entered Swarthmore College in 1940, taking his B.S. in physics in 1944. He served with the Signal Corps Radio Propagation Unit during World War II. He was employed by the Mutual Broadcasting System after his discharge in 1945, as chief of its Plans and Allocations Division from 1947 to 1949 when he resigned to do graduate work at Cornell University. Dr. Smith received his M.S. from Cornell in 1951 and completed residence requirements for his Ph. D. in 1954 while on leave of absence from the Bureau. His Ph. D. was awarded by Cornell in 1956.

### Robert W. Knecht

Mr. Knecht succeeds Dr. Smith as Chief of the Ionosphere Research and Propagation Division. He joined the National Bureau of Standards in June 1949 immediately upon graduation from Union College in Schenectady, N.Y., with a B.S. in physics. After an initial assignment in Washington, he was transferred to Alaska, spending 8 months at Barrow Radio Propagation Field Station and, subsequently, 2 years at Anchorage as physicist-in-charge of the North Pacific Radio Warning Service.

Since his return from Alaska in 1954, Mr. Knecht has worked primarily in the fields of ionospheric physics and solar-terrestrial relationships. He was formerly chief of the Sun-Earth Relationships Section. After exploring the possibilities of a satellite-borne topside sounding experiment for studying the ionosphere, Knecht promoted the development of TOPSI, the U.S. fixed-frequency topside sounding satellite scheduled for launching in the first half of 1963. Overall planning of the experiment and analysis of results are the responsibility of CRPL under Knecht's leadership. The National Aeronautics and Space Administration is responsible for the technical management of the overall program.

# Publications of the National Bureau of Standards

### Periodicals

*Technical News Bulletin*, Vol. **46**, No. 12, December 1962. 15 cents. Annual subscription: $1.50; 75 cents additional for foreign mailing. Available on a 1-, 2-, or 3-year subscription basis.

*Basic Radio Propagation Predictions* for March 1963. Three months in advance. CRPL–220, issued December 1962. 15 cents. Annual subscription: $1.50; 50 cents additional for foreign mailing. Available on a 1-, 2-, or 3-year subscription basis.

*Journal of Research of the National Bureau of Standards*

*Section A. Physics and Chemistry*. Issued six times a year. Annual subscription: Domestic, $4; foreign, $4.75.

*Section B. Mathematics and Mathematical Physics*. Issued quarterly. Annual subscription: Domestic, $2.25; foreign $2.75.

*Section C. Engineering and Instrumentation*. Issued quarterly. Annual subscription: Domestic, $2.25; foreign $2.75.

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